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ABSTRACT

This student module on vibration and noise control is one of 50 modules concerned with job safety and health. Following the introduction, nine objectives (each keyed to a page in the text) the student is expected to accomplish are listed (e.g., Compare four strategies for vibration control). Then each objective is taught in detail, sometimes accompanied by illustrations. Learning activities are included. A list of references and answers to learning activities complete the module. (CT)

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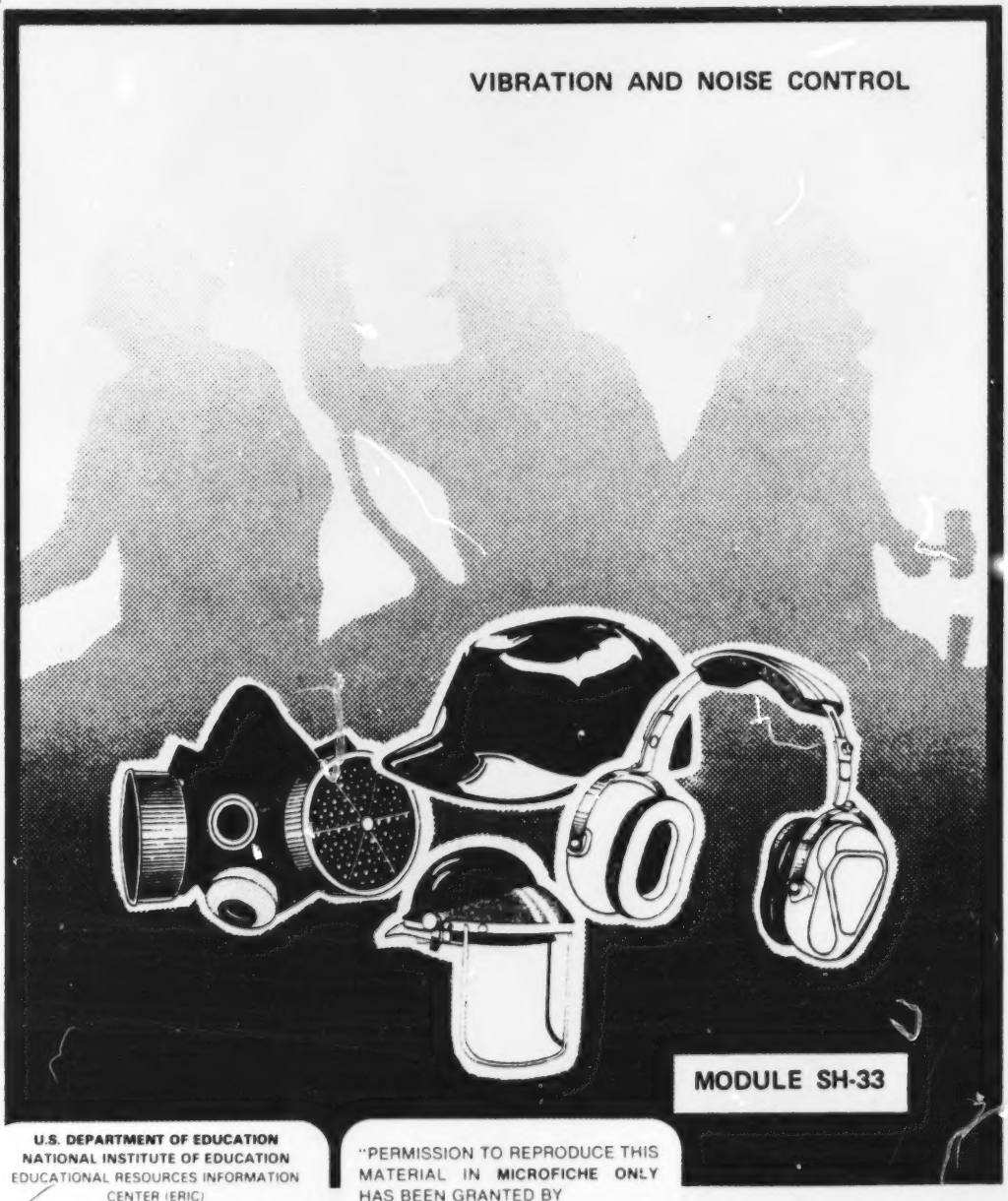
SAFETY AND HEALTH

VIBRATION AND NOISE CONTROL



MODULE SH-33

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The Center for Occupational Research and Development
601 Lake Air Drive, Suite C
Waco, Texas 76710

INTRODUCTION

Some workplace hazards injure or kill instantly. Noise doesn't. It slowly but steadily affects workers through the years in ways they seldom notice.

Increasing public awareness has shown that noise is much more than just an annoyance. Excessive noise can cause permanent hearing loss of varying degrees, leading to premature legal deafness. Loss of hearing caused by excessive noise on the job has resulted in a growing number of lawsuits, with awards totaling millions of dollars a year. There is also growing awareness of new scientific evidence showing that noise affects body chemistry and increases blood pressure and heartbeat. Continuous noise above the range of 85 decibels affects job performance and can have harmful effects on mental health.

Nowhere is noise more common or dangerous than in the workplace. A conservative estimate (by the National Institute for Occupational Safety and Health) is that over 10 million U.S. workers are being exposed to harmful levels of noise. To try and reduce noise-induced hearing loss, limits have been set on the levels of noise permissible in the workplace.

It is the goal of this module to inform and educate both workers and concerned individuals about the problems of noise and its control.

OBJECTIVES

Upon completion of this module, the student should be able to:

1. Briefly define noise and its three components. (Page 3)
2. Identify the units of measurement involved in noise measurement procedures. (Page 4)
3. List and give examples of three effects that noise has on workers. (Page 7)
4. Describe the most desirable method of controlling noise. (Page 14)
5. List the three main ways to control and solve a noise problem that already exists. (Page 15)
6. Describe the two major types of personal hearing protection devices. (Page 19)
7. Compare four strategies for vibration control. (Page 21)
8. Explain noise exposure limits and how they are determined. (Page 23)
9. Describe a basic hearing conservation program. (Page 25)

OBJECTIVE 1: Briefly define noise and its three components.

Noise, in common terms, is defined as any unwanted sound. It has also been described as sound without value. To understand noise and how it affects the industrial worker, as well as any human exposed to it, one must first understand certain fundamentals of sound and of human responses to it.

Sound is produced when an object produces vibrations (sound waves) that travel through some media (usually air) and activate the hearing mechanism of humans. Sound waves travel through the air like waves through water. The higher the wave, the greater its power (intensity or loudness). The greater the number of waves a sound has, the greater its frequency (or pitch).

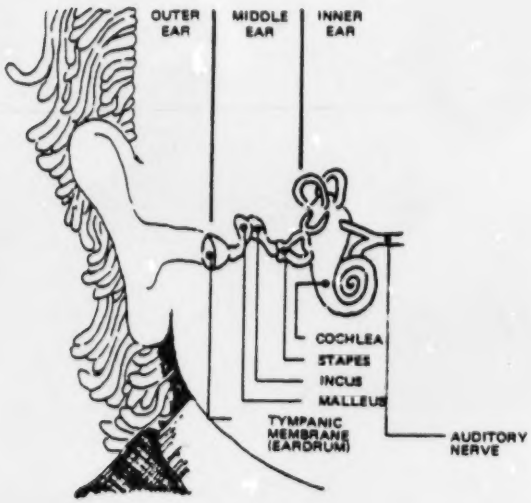

Figure 1. Human hearing system.

The human ear enables a person to receive and interpret sound. The ear is made up of skin, flesh, membranes, muscles, cartilage bones, and nerves. Its function is to transmit to the brain an accurate pattern of sound vibrations received from the environment, including how loud the sound is and from which direction it comes.

The human hearing system may be divided into three main sections: (1) the outer ear, (2) the middle ear, and (3) the inner ear. (Figure 1.) The outer ear acts like a funnel to direct the sound waves from the air to the tympanic membrane (commonly known as the eardrum). Sound causes the eardrum to vibrate. These vibrations cause the three bones in the middle ear (malleus,

incus, and stapes) to move mechanically. The middle ear sends these mechanical vibrations to part of the inner ear (cochlea), where they are picked up by tiny hair cells (cilia) and sent as electrical impulses along the auditory nerve to the brain. Here they are perceived as sound or, depending on the circumstances, as noise.

Before trying to control noise, one must first understand the parts involved. There are three components of sound: (1) a source that gives off sound energy, (2) a path along which the sound energy travels, and (3) a receiver of the sound energy (such as the human ear). Knowing these relationships helps in understanding a noise problem and in deciding on the changes that will be necessary for noise control. If each part of the "system" - source, path, and receiver - is studied carefully, the solution to the problem will be much easier.

ACTIVITY 1:*

1. In one sentence, define noise. _____

   _____

2. List the three components of noise.

   a. _____

   b. _____

   c. _____

OBJECTIVE 2: Identify the units of measurement involved in noise measurement procedures.

Sound is described in three different ways:

- Amplitude - how loud or intense the sound is.
- Frequency - the pitch (highness or lowness) of the sound.
- Duration - how long the sound lasts.

*Answers to Activities appear on Page 29.

The amplitude (fullness) of sound is measured in units called "decibels" (abbreviated dB), named in honor of Alexander Graham Bell. The higher the decibel level is, the louder the noise. In general, the weakest sound that can be heard by a person with very good hearing in an extremely quiet location is given the value of 0 dB. The threshold of pain is reached at sounds of 140 dB.

How loudness is interpreted varies widely between individuals: what may seem loud to one person may not to another. This is a matter of personal judgment and it may even reveal a hearing loss. However, consistent measurement of sound is made possible by use of the decibel scale. This scale, shown in Table 1, measures sound pressure or energy according to international standards.

TABLE 1. DECIBEL LEVEL SCALE.

SOUND LEVELS AND HUMAN RESPONSE					
Common Sounds	Noise Level (dB)	Effect	Alarm clock (2 feet) Hair dryer	80	Annoying
Carrier deck jet operation Air raid siren	140	Painfully loud	Noisy restaurant Freeway traffic Man's voice (3 feet)	70	Telephone use difficult
	130		Air conditioning unit (20 feet)	60	Intrusive
Jet takeoff (200 feet) Thunderclap Discotheque Air horn (3 feet)	120	Maximum vocal effort	Light auto traffic (100 feet)	50	Quiet
			Living room Bedroom Quiet office	40	
Pile drivers	110	Uncomfortably loud	Library Soft whisper (15 feet)	30	Very quiet
Garbage truck	100	Very loud	Broadcasting studio	20	
Heavy truck (50 feet) City traffic	90	Very annoying Hearing damage (8 hours)		10	Just audible
				0	Hearing begins

This decibel (db) table compares some common sounds and shows how they rank in potential harm to hearing. Note that 70 dB is the point at which noise begins to harm hearing. To the ear, each 10 dB increase seems twice as loud.

The decibel scale is logarithmic (based on multiples of ten), and not linear like a ruler. Therefore, a small increase in decibels represents a much greater increase in loudness. For example, while 10 decibels is 10 times louder than 1 decibel, 20 decibels is 100 times louder (10 x 10, rather than 10 + 10), 30 decibels is 1000 times louder (10 x 10 x 10) and so on. Thus, the sound amplitude multiplies by 10 with every 10-decible increase. The reason for such a scale is simply that the human ear is sensitive over such a wide range of sounds that the numbers involved had to be compressed for convenience.

Frequency is measured in Hertz (abbreviated Hz). Frequency or pitch is determined by how rapidly the sound source vibrates. It is measured by the number of sound waves passing a given point in one second. For example, if a tuning fork vibrated 500 times per second, then the frequency or pitch would be 500 cycles per second, or, more commonly, 500 Hz. However, the human ear does not hear all frequencies. A person's normal hearing ranges from 20 Hz to 20,000 Hz or, roughly, from the lowest note on a great pipe organ to the highest note on a violin.

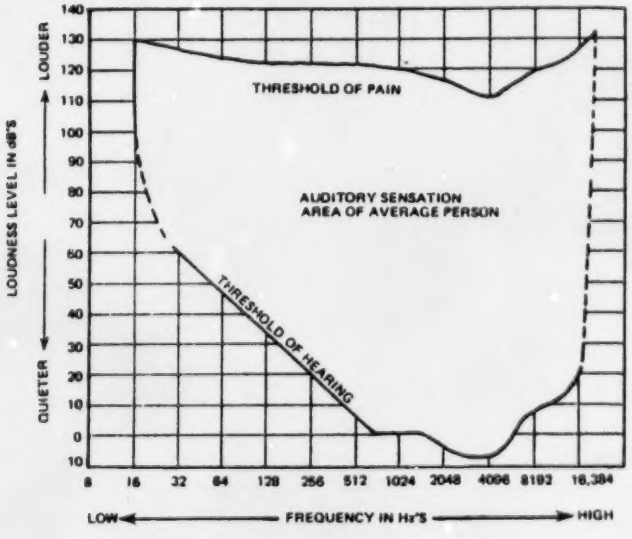

Figure 2. Sensitivity scale of human ear.

The human ear does not hear all sounds equally. Very low and very high notes (such as 25 Hz and 18,000 Hz) are much harder to hear than a sound of the same strength at 1000 Hz. Figure 2 shows that the human ear is much less sensitive to the lower frequencies. Notice that a sound at 1024 Hz can be heard at 0 dB. But a sound at 64 Hz (a lower frequency) must be almost 50 dBs for an average person to hear it. This presents a 40 dB increase (or 10 x 10 x 10 x 10 = 10,000 times the level of loudness required). Also

notice that a sound of 4,096 Hz at 120 dBs is not audible (cannot be heard) and is even beyond the threshold of pain.

It is important to consider duration in any study of noise, since much noise-induced hearing loss arises from continuous exposure to excessive noise. Because of this, the permissible limits of exposure to continuous noise have been set for periods of eight hours, the usual length of a work-day. Noise is measured by sound-level meters on a scale called the A-frequency weighting scale. (This "A" scale discriminates against low frequency sounds.) Sound-level meters measure sound in a manner similar to that of the human ear. The current (at time of writing) permissible limit for continuous noise, for an exposure of eight hours a day, is 85 decibels on the A scale (85 dBA). For impact-type noises (sudden sharp noises) the limit is 140 dBA, and such noises must be only momentary.

ACTIVITY 2:

1. List the three different terms describing sound, and briefly describe what each term means.
   a. _____
   b. _____
   c. _____
2. Name the two units of measurement for sound, and give a brief explanation of each.
   a. _____
   b. _____

OBJECTIVE 3: List and give examples of three effects that noise has on workers.

The effect that noise may have on a person is a major element of concern. Exposure to excessive noise can have both short-term and long-term harmful effects on individuals, depending upon six factors:

- The nature of the noise.
- The level of loudness.

- The proximity of the individual to the noise source.
- The frequency or pitch of the noise.
- The duration of the noise.
- The physical and mental condition of the individual involved.

Three general ways noise may affect a worker include: physically, psychologically, and it may interfere with communication and job performance. A discussion of each follows.

PHYSIOLOGICAL EFFECTS

Of the many health hazards related to noise, hearing loss is the most clearly observable and measurable by health professionals. In recent years, studies by government and private researchers have revealed startling new facts about noise as a cause of deafness and a contributor to various medical problems. For example, it has been found that over 10 million Americans suffer from hearing loss caused by noise in their workplace.

Threshold shift is the technical term for physical hearing loss. This term refers to a decrease in a person's ability to hear weak or faint sounds, rather than a complete loss of hearing. The hearing loss may be only temporary, disappearing after quiet is restored; or it may be permanent, as a result of continuous exposure to loud noises. The exact mechanism by which the shift occurs is not totally clear, but the phenomenon is familiar to anyone who has had a loud firecracker or gun go off very close to his or her ear.

Any steady noise over 85 dB will produce permanent threshold shift in the normal ear if exposure is daily over a substantial period of time. Persons more susceptible to noise may suffer hearing loss from daily exposure to steady noise over 80 dB. Noise levels of 135 dBs or greater can be instantaneously damaging to the ear. An individual should never be exposed to this high a noise level.

Research in animals as well as in people shows that loud noise that reaches the inner ear attacks the hair cells of the hearing organ (within the cochlea). As the noise becomes louder and as the exposure to it increases, a greater proportion of the hair cells are damaged and eventually destroyed. The function of the hair cells is to change the mechanical ener-

gy reaching the ear into nerve impulses, which are then carried by the auditory nerves to the brain. Hair cells will not grow back, so progressive loss of hair cells is inevitably accompanied by progressive loss of hearing.

Hearing loss from excessive noise, for the most part, cannot be reversed. Scientists note that a hearing aid cannot make up for lost hearing the way glasses can improve poor eyesight, although hearing aids can be of limited help to some people.

When hearing loss occurs, it is in most cases a gradual loss, becoming worse with time. Consider the case of a worker who completes his or her first day in a noisy factory. The worker probably recognizes that the workplace is noisy and may even feel the effect as a "ringing in the ears" (known as tinnitus). This person suffers a temporary hearing loss (threshold shift) that is centralized in the frequency range around 4000 Hz. as shown in Figure 3. This person will not hear moderately high frequencies well, but perception of low-frequency and very high-frequency sounds will be

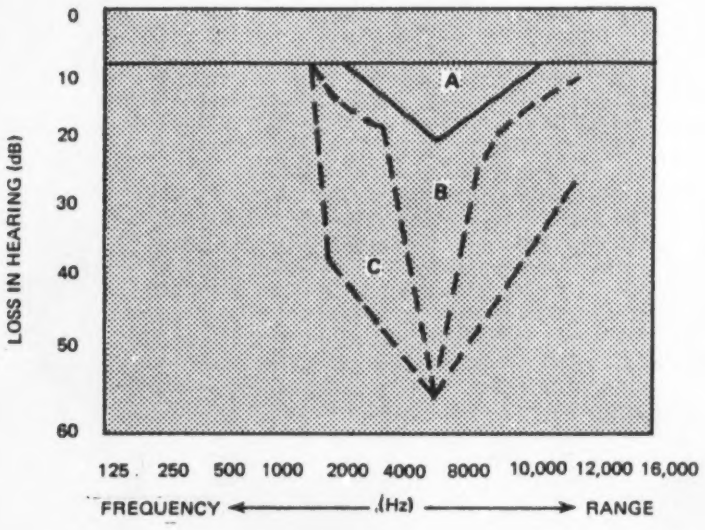

Figure 3. Patterns of hearing loss from exposure to industrial noise. a. Temporary loss of hearing; b. after 10 years; c. after 35 years. (Note that in each case, the greatest loss comes around the 4000 Hz frequency.)

unaffected. As the person leaves the factory, most sounds will seem quieter. His or her car will seem to be better insulated, and the usual rattles and squeaks will not be heard. This person may judge other person's voices to be soft, as if they were speaking through a blanket.

By morning, the ringing in the ears will have stopped, and hearing will be partly but not completely restored. That day the factory will not seem quite as noisy as it was on the first day. As the months go by, this person will become more and more used to his or her condition, but, in reality, the condition will be getting worse. If the exposure continues, hearing loss will become irreversible, and will eventually result in deafness. Figure 3 shows a typical downward progression of hearing loss due to prolonged exposure to industrial noise. It is important, however, to realize that most people will lose some hearing (from various environmental noise sources) as they grow older. This aging effect is called presbycusis.

Many experts believe that loss of hearing is not the most serious physiological consequence of excessive noise. The first effects of noise are anxiety and stress. These reactions accompany a change in the hormone content of the blood, which in turn produces changes such as high blood pressure, increased heart rate, digestive spasms, and tensing of the muscles. In certain noisy industries, cases of ulcers among workers have been found to be up to five times as numerous as would normally be expected.

Perhaps the most serious effect of noise is its relationship to heart disease. While no one has yet shown that noise causes any direct damage to the heart itself, recent evidence strongly suggests a link between exposure to noise and the development and aggravation of a number of heart disease problems. The best available studies are those that have been conducted in industrial settings. For example, steel workers and machine shop operators laboring under the stress of high noise levels had a higher incidence of circulatory and heart problems than did workers in quiet industries.

Noise, however, is only one of several environmental causes of stress. For this reason, researchers cannot say with total confidence that noise alone causes the heart and circulatory problems noted. What they can point to is a statistical relationship that has been found in several studies.

Doctors and health researchers also agree that all persons must have rest and relaxation at regular time periods to maintain adequate physical (and mental) health. Exposure to noise may interfere with this requirement and thus lower a person's resistance to disease and infections.

PSYCHOLOGICAL EFFECTS

One effect of noise that does not seem to depend entirely on loudness level is annoyance. This is a form of psychological effect. Under certain circumstances, a dripping water faucet or a squeaky engine can be as annoying as a jackhammer. Nevertheless, it is safe to say that, in general, the louder the noise is, the more annoying it is.

Annoyance frequently accompanies other effects that noise has on people, such as sleep disruption. Noise can make it difficult to fall asleep, or easier to awaken, or it can cause shifts from deep to lighter stages of sleep. Whenever noise interferes with a person's sleep, demands are made on both the mental and physical health of the person.

When noise becomes sufficiently loud or becomes particularly annoying, a person's initial response may become extreme and his or her behavior unusual. When this happens, tempers may flare at the slightest provocation. Newspaper files and police records contain reports of numerous incidents in which noise has triggered extreme behavior. For example, a night clerical worker, upset about noise outside his apartment, shot one of the persons causing a disturbance after several warnings to stop the noise had been ignored. In another situation, sanitation workers and construction personnel were threatened when the noise they produced annoyed others.

INTERFERENCE WITH COMMUNICATION AND JOB PERFORMANCE

One of the most bothersome aspects of noise is its interference with conversation. People with some degree of hearing loss may not hear parts of normal conversations, and this may result in frustration and annoyance with the person speaking. Individuals who often have to raise their voices to be heard over background noise sometimes lose the ability to speak at normal volume levels. Persons who work or live in noisy environment thus tend to

communicate and interact less than others, mainly because of frustration. While noise can destroy the hearing ability of individuals, a person with partial deafness from exposure to noise does not necessarily live in a quieter world. Many sounds that can be heard by such a person are distorted in loudness, pitch, apparent location, or clarity. Certain high frequency sounds such as "s", "sh", "ch", "t", and "f" are often lost or indistinguishable, and the meaning of a conversation is thus distorted.

Noise not only makes conversation difficult, but also hinders job performance and work efficiency. In general, noise is more likely to reduce the accuracy of work rather than the total quantity. Noise also takes a greater toll on complex tasks than it does on simpler ones. When noise is loud or long-lasting, errors in a worker's observation and judgment usually take place. Loud noise can also lead to breaks in a worker's concentration, and thus cause a change in work rate.

Many times noise does not interfere with the work at hand, but has a bad effect on the quality of work that is performed after the noise stops. Research suggests that people who work in the midst of high noise levels are likely to have frustration and aggravation that carry over into their life after working hours. Relaxing at home after a noisy workday may not be an easy thing to do. If the home itself is noisy, the tired and irritated worker may not be able to work out the day's accumulated stress during the course of the evening.

Noise in industrial settings has a significant effect on job performance and employee health. A coal industry study indicated that varying noise conditions during mining operations cause distraction leading to poor work performance. Other studies have confirmed additional effects of noise exposure, including exhaustion, absentmindedness, mental strain, and absenteeism - all of which affect worker efficiency.

Even the most common business office is not immune to job interference due to noise. The quality of telephone communication carried on in noisy environments is estimated in Table 2. This interference with communication is more important than may be apparent, since studies have shown that noise and miscommunication increase tension between office workers and their supervisors.

TABLE 2. TELEPHONE COMMUNICATION IN NOISY ENVIRONMENTS.

Noise Level in the Environment in dBs	Quality of Communication
85 and above	Unsatisfactory
70 - 85	Difficult
55 - 70	Slightly difficult
Below 55	Satisfactory

Finally, noise may have serious effects upon accident prevention and occupational safety. The Federal Railroad Administration is aware of this hazard and has identified "high noise-level conditions" as a possible contributor in 19 accidents that caused the deaths of 25 railroad employees in a 22-month period.

The health and safety of industrial workers is often endangered by noise loud enough to mask (hide) warning signals. In the case of an accident that occurred in an auto glass manufacturing plant, noise levels were so high that a worker whose hand was caught in manufacturing equipment received no help because no one could hear his screams. Likewise, in a noisy Ohio plant, two pressroom auto workers were permanently disabled when they failed to hear approaching panel racks and warning shouts. Obviously, employees with noise-induced hearing losses are even more susceptible to accidents than workers with unimpaired hearing.

ACTIVITY 3:

List three major effects of noise upon workers and give one example of the effects of each.

1. _____
   _____
2. _____
   _____
3. _____
   _____

OBJECTIVE 4: Describe the most desirable method of controlling noise.

AVOIDING THE PROBLEM

The most desirable method of controlling noise in the workplace is avoiding the problem in the beginning. Good planning before a plant or business is in operation solves many of the problems before they occur. The possibility of excessive noise levels should first be considered at the building planning stage. Building planning includes building design and plant layout, the proper use of materials in construction, and the selection and installation of noise-controlled equipment. Choosing noise-controlled equipment is helpful, but proper placement of such equipment is also necessary if noise is to be properly controlled. For example, a certain machine may be selected for use because its loudness level is less than 90 dB. However, if an identical machine is placed nearby, without proper precautions, the sound level produced by the two machines may be 95 dBs at the operator's station.

Noise control can often be designed into the building and equipment on an economical and practical basis without giving up designed goals. Unfortunately, not all businesses have such foresight, and many industrial operations were built before the effects of noise on workers were known. Also, some industrial processes are just plain noisy by their nature. Thus, the second and most commonly used method for solving noise problems is to control the existing problem.

CONTROLLING EXISTING PROBLEMS

Controlling noise problems that already exist is usually much more difficult and costly than designing noise control into the building during construction. The existing equipment within any plant was probably selected on the basis of being the most economical and efficient method of production, and a noisy working environment is often the result. The application of

engineering principles of noise control can usually reduce noise to any desired degree. Completely redesigning or fully replacing equipment is usually successful, but economic consideration and/or operational necessities often make such solutions impractical. Unfortunately, a standard technique or procedure to remedy most noise problems while still adequately satisfying other considerations cannot always be found. Similar machines, processes, or noise sources in two different locations may present two entirely different problems that need to be solved in very different ways.

With this in mind, a complete, detailed analysis of each individual problem must be carried out before an attempt to remedy the situation is made. The procedures for this analysis includes gathering qualitative and quantitative information, comparing it to acceptable noise levels, then selecting the correct control measures. Engineering control of industrial noise problems requires the skill of individuals who are highly trained in this area.

ACTIVITY 4:

(Circle the correct answer.)

The most desirable method for noise control is to:

a. Control the existing problem.

b. Completely re-do a problem situation.

c. Avoid the problem to begin with.

d. None of the above answers is correct.

OBJECTIVE 5: List the three main ways to control and solve a noise problem that already exists.

Noise consists of three components - a source, a path, and a receiver. Therefore, to control a noise that already exists, one of the three components of noise must be changed. This can be done by:

- Minimizing the source.
- Interrupting the path of transmission.
- Protecting the receiver.

Figure 4 shows the three components of a noise problem and examples of its control.

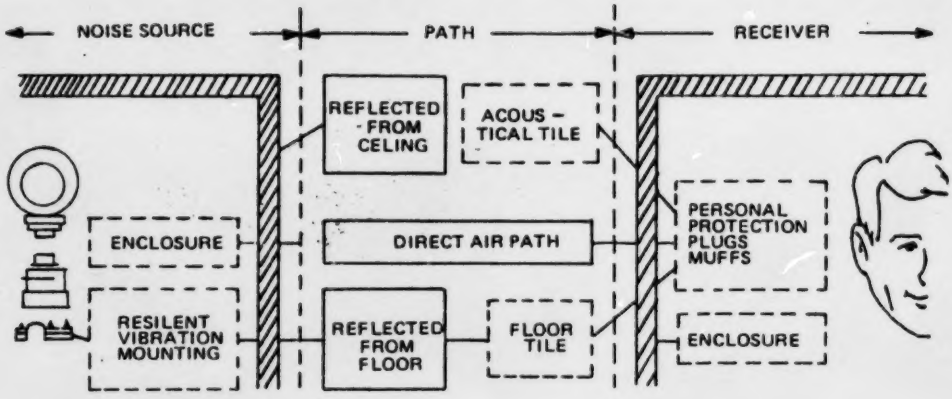

Figure 4. The three components of every noise problem.

MINIMIZING THE SOURCE

The most desirable method of controlling a noise problem is to minimize the noise at the source. This generally means the modification of existing equipment or the replacement of noisy equipment with quieter equipment. All too often major changes such as these are impractical, so minor changes are more frequently used. One of these changes might be to modify technological approaches to accomplish necessary goals more quietly. For example, rotary saws might be used instead of jackhammers to break up street pavement. Ultrasonic pile drivers might replace the noisier steam-powered, impact-type pile drivers, and so on.

Perhaps one of the most important methods of minimizing noise sources is through proper upkeep and repair of equipment. Sometimes, the most severe noise problem can be handled by maintenance personnel. Recognizing exactly where the noise is coming from is usually the most difficult task in solving a noise problem. A little "detective" work can sometimes uncover the source of the problem as well as its solution.

Other methods of minimizing the source of noise include the muffling of exhausts and the changing of operational procedures.

INTERRUPTING THE PATH

Often, a piece of machinery turns out to be excessively noisy. When this occurs, an acoustical (sounds) engineer may be called in to "sound-proof" the machine. Under such circumstances, the engineer may be forced to modify existing features that should never have been accepted in the first place. Therefore, much of the engineer's effort may be applied not to the source of the noise, but to the path between the sound and the receiver.

Sound (noise) travels through air. It also travels through solids such as wood. Such solids vibrate in response to the sound and do not effectively interrupt the transmission of sound. Machines that contain cams, gears, and metal stops often produce loud noise levels. The use of sound-absorbing materials on walls, ceilings, and floors helps reduce the transmission of noise to other areas. Table 3 shows various sound-absorbing materials and their respective absorption coefficients at different frequencies. (NOTE: The larger the number, the greater the amount of noise absorption.)

TABLE 3. SOUND ABSORPTION COEFFICIENTS OF CERTAIN MATERIALS.

Materials	Frequency (Hz)		
	125	1000	4000
Glazed brick	0.01	0.01	0.02
Coarse concrete block	0.36	0.34	0.63
Heavy carpet on concrete	0.002	0.37	0.65
Carpet on foam rubber pad	0.08	0.69	0.73
Linoleum floor on concrete	0.02	0.03	0.02
Wood floor	0.15	0.07	0.07

Noise interruption along the path can also be accomplished in other ways:

- By shielding or enclosing the source.
- By increasing the distance between the source and the receiver.

- By placing a shield between the source and the receiver.

It is also possible to build mechanical interruption of the sound waves into certain kinds of equipment. Devices that function in this way are called mufflers.

PROTECTING THE RECEIVER

The individual (the receiver) can be protected from noise damage by shielding. In this case, an enclosure surrounds the receiver instead of the source. The amounts of noise reduction achieved by various enclosures will differ. Generally, a single-wall enclosure with no openings between the source and the receiver provides a 2-5 dB reduction in the low frequencies and a 10-15 dB reduction in the high frequencies. Enclosures with added sound-absorbing materials may provide a noise reduction of 10-15 dB for low frequencies and in excess of 30 dB for high frequencies.

The person exposed to noise can also be protected by proper management policies, including the changing of job schedules and the rotation of personnel. Such policies reduce the exposure to excessive noise that any one employee may receive. In a factory, for example, shift rotations may reduce serious exposure by ensuring that workers take turns at the noisy jobs.

The final line of defense against noise involves the worker directly and involves the use of hearing protection devices such as ear plugs and ear muffs. Despite all of the methods of control previously mentioned, it is sometimes virtually impossible for an employee to avoid exposure to potentially harmful sound levels. In such a situation, personal hearing protectors should be used.

ACTIVITY 5:

List the three main ways to control a noise problem that already exists and give an example of each.

1. _____
2. _____
3. _____

OBJECTIVE 6: Describe the two major types of personal hearing protection devices.

When engineering noise controls are not possible, or when they are only partially successful, personnel should be protected from the effects of excessive noise levels by the use of suitable hearing protection devices. Personal hearing protection devices are acoustical barriers that reduce the amount of sound energy transmitted through the outer and middle ears to the receptors in the inner ear. The two major types of these protective devices are: ear plugs (or inserts) and ear muffs. (Figure 5.) Ear plugs provide an accoustical seal at the entrance to the outer ear canal. Ear muffs are worn over the external ear, providing an acoustical seal against the head. Well-fitting protective muffs are more effective, but properly fitted inserts also do a good job. Since ear canals differ widely in size, shape, and position, plugs or inserts should be separately fitted for each ear. In many cases, there is only a small space available to accommodate an ear plug, but almost all entrances to ear canals can be opened and straightened by pulling the external ear directly away from the head, making it possible to fit an ear plug securely.

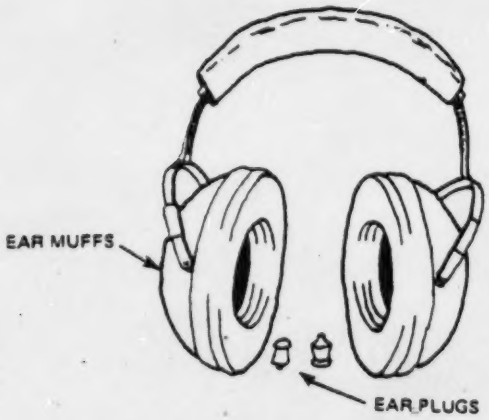

Figure 5. Personal hearing protective devices.

Protective ear muffs should be adjustable to provide a good seal around the ear, proper tension of the cups against the head, and comfort. Generally, the size of the enclosed volume within the muff's outer shell is directly related to low frequency noise control.

Both types of protectors are well worth the small inconvenience they cause the wearer. Once acquired, the habit of wearing a hearing protector

becomes second nature and will not affect a worker's routine. Hearing protectors are especially recommended for such working environments as construction, lumbering, mining, and steel and textile mills. However, personal protection devices do have some limitations. The effectiveness of a hearing protector depends on its design as well as on several physical features of the wearer. Sound energy can reach the inner ears of persons wearing protectors by four different pathways:

- By passing through bone and tissue around the protector.
- By causing vibration of the protector, which in turn generates sound into the external ear canal.
- By passing through leaks in the protector.
- By passing through leaks around the protector.

These pathways are illustrated in Figure 6.

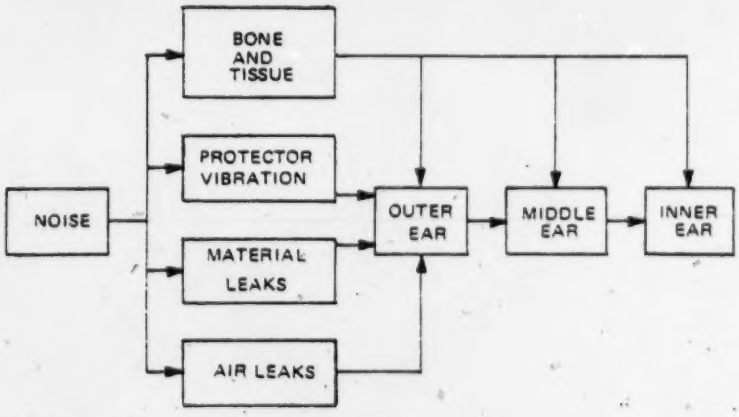

Figure 6. Sound reaches the inner ear of a person wearing a protector by different methods.

ACTIVITY 6:

Name the two major types of personal hearing protection devices and one characteristic of each.

1. _____
2. _____

OBJECTIVE 7: Compare four strategies for vibration control.

The principles of vibration control are much the same as those for noise control. If there is a great deal of vibration, there is usually a lot of noise, so both noise and vibration must be controlled together. Vibration problems are usually found in operations where heavy industrial equipment is used. Any solid structure such as a floor, wall, cover plate, or enclosure can act as a "sounding board" for the source of the vibration, thus creating different kinds of noise problems. Even though proper noise control procedures may have been used in correcting the noise source directly, noise may still be present if there is solid contact between the source and the floor with no vibration control. For example, a printing press is located on the second floor of a newspaper office building. The employer realizes the potential noise hazards associated with the use of the press and places an enclosure lined with sound-absorbing materials around the press. However, the noise continues to be a problem on the first floor office underneath the press because no vibration control measures were used.

There are four basic strategies for vibration control of noisy equipment and machinery.

1. Vibration can be reduced by replacing vibrating machines with machines that vibrate less. This is often not feasible and can be very costly.
2. Vibration can also be reduced by slowing down the machine's speed and/or the forces that drive it. This may slow down production.
3. Regular maintenance is very important in controlling vibration and noise. This is often the least costly method, and also saves on the wear and tear of the equipment in use. Maintenance includes correct balancing and aligning, frequent lubrication, replacing old and worn parts, and even tightening loose nuts and bolts.
4. Vibration isolation is commonly used in industrial operations. There are several relatively inexpensive ways in which the vibration source can be isolated and quieted. Among these are the use of damping mate-

rials such as rubber, anti-vibrational blocks to act as shock absorbers, and physical barriers. Simply separating the source from the worker is often unreliable, except when the distance between the worker and the noise source is great. Figure 7 illustrates how vibration isolation mounts are used to isolate and quiet vibration noise from a compressor and piping assembly.

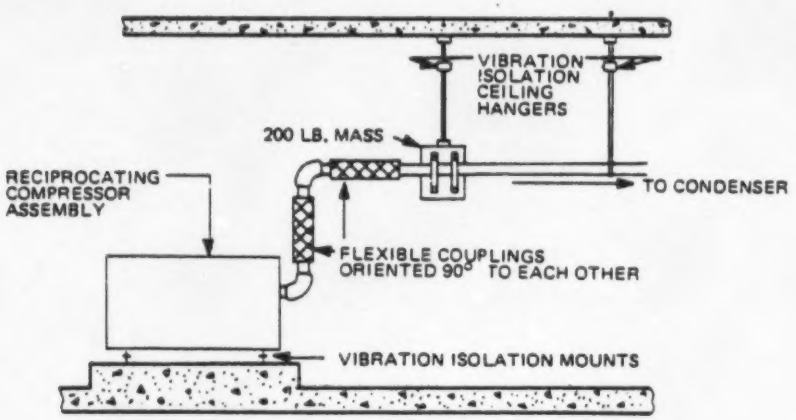

Figure 7. Vibration isolation mounts used to quiet vibration noise from a compressor and piping assembly.

ACTIVITY 7:

Name the four strategies for vibration control and list one advantage or disadvantage of each.

1. _____
2. _____
3. _____
4. _____

OBJECTIVE 8: Explain noise exposure limits and how they are determined.

Protecting employees against hearing loss from industrial noise requires the establishment of standards and limits for safe noise exposure. The noise exposure limits set forth in OSHAct (Occupational Safety and Health Act) are designed for both continuous and impact-type (a sharp burst of sound) noises. The continuous noise limit was set at 90 DB(A) measured for an exposure of eight hours per day on an A-frequency weighting scale (a scale used by sound level meters that measures sound in much the same way as the human ear would). For every decibel higher, the exposure time that is permitted becomes less (for example, 95 dB(A) for 4 hours, 100 dB(A) for 2 hours, and so on). Exposures to continuous noise levels greater than 115 dB(A) are not allowed under any circumstances. The limit to impact-type noise exposures is 140 dB(A). Table 4 lists the January, 1981, standards for noise level regulation enforced by the Occupational Safety and Health Administration (OSHA).

TABLE 4. OSHA STANDARDS FOR NOISE LEVEL REGULATION.

Maximum Exposure Time Per Day, Hr.	January, 1981 Regulation Noise Level dB(A)	Probable Future Regulation Noise Level dB(A)
8	90	85
6	92	87
4	95	90
3	97	92
2	100	95
1 1/2	102	97
1	105	100
1/2	110	105
1/4	115	110

The National Institute for Occupational Safety and Health (NIOSH) was established in the OSHAct to conduct research and to recommend new occupational safety and health standards. NIOSH recommended that the present standards be lowered to new levels (Table 4), and in August, 1981, the maximum permissible level became 85 dBA. Future regulations for limiting worker exposure to industrial noise may be even more restrictive than existing regulations.

It should be noted that the noise exposure limits specified in the OSHA regulations are set forth as the safest limits feasible with due consideration given to other factors, such as economic impact and available technology. The OSHA regulations, where used, will effectively protect approximately 85 percent of exposed individuals from permanent hearing damage due to industrial noise.

ACTIVITY 8:

Circle the correct answer.

1. The maximum exposure time for a noise level of 105 dB(A) per day under January, 1981, OSHA regulations is:
   a. 3 hours.
   b. 2 hours.
   c. 1 hours.
   d. 1/2 hour.
2. Circle True or False.
   a. The continuous noise limit is measured on the A-scale. True False
   b. Noise limits by OSHA will protect all workers from hearing damage. True False
   c. Noise limit regulations are never changed. True False

OBJECTIVE 9: Describe a basic hearing conservation program.

The objective of a hearing conservation program is to prevent noise-induced hearing loss and other related health concerns. Simple compliance with local, state, or federal rules and regulations generally will not prevent hearing loss in all individuals. These laws are compromises between known health research and economic productivity. However, it may be economically feasible to select lower exposure limits that will be more protective. The lowest and safest practical limits are obviously best for the well-being of the workers. In addition, these low limits may be of large economic value to the employer in the long run, because they will minimize compensation claims for noise-induced hearing loss. Furthermore, it is likely that the reduced noise levels will result in better overall working conditions that may contribute to safety and increased production.

The effectiveness of a hearing conservation program depends upon the cooperation of employers, supervisors, employees, and other concerned individuals. Management's responsibility in this type of program is four-fold:

- Conducting noise measurements.
- Initiating noise control measures.
- Providing hearing protective equipment when necessary.
- Informing employees of the benefits to be derived from a hearing conservation program.

It is the employee's responsibility to make proper use of the protective equipment provided by management. It is also the employee's responsibility to observe any rules or regulations in the use of equipment to minimize the noise level exposure. To ensure the use of hearing protective equipment, workers must first be convinced of its necessity. The following table (Table 5) gives estimates of the number of production workers exposed to continuous noise levels of an 85 to 100 dB(A). The 19 industrial categories listed are intended to be representative of industry as a whole.

TABLE 5. SOUND LEVELS ENCOUNTERED BY WORKERS IN 19 INDUSTRIAL CATEGORIES.

Industry	85-90 dB(A)	90-95 dB(A)	95-100 dB(A)
Food and Kindred Products	7,498	16,853	2,580
Tabacco Manufacturers	58	288	184
Textile Mill Products	18,030	15,380	10,751
Apparel & Other Textile Products	1,028	--	--
Lumber and Wood Products	4,119	24,585	12,359
Furniture & Fixtures	7,469	2,960	--
Paper and Allied Products	7,638	10,211	152
Printing and Publishing	21,706	9,120	--
Chemicals & Allied Products	8,428	11,596	347
Petroleum and Coal Products	2,888	2,888	1,732
Rubber and Plastic Products	5,438	2,981	168
Leather & Leather Products	212	--	--
Stone, Clay & Glass Products	3,446	238	--
Primary Metal Industries	22,990	18,805	10,161
Fabricated Metal Products	12,976	6,850	9,447
Machinery, except Electrical	15,769	8,454	3,416
Electrical Equipment & Supplies	5,434	1,740	68
Transportation Equipment	11,988	6,448	6,446
Electric, Gas, & Sanitary Servs.	25,387	18,576	--
Total	182,502	157,973	57,812

Workers exposed to continuous sound levels of 85 to 100 dB(A)	3,982,870
Workers exposed to continuous sound levels higher than 100 dB(A)	296,880
Total Workers Exposed	4,279,750

With numbers of exposures to noise levels such as these, it is apparent that each business involved should have a hearing conservation program.

General procedures for carrying out an industrial hearing conservation program are as follows:

- Evaluation of noise exposures and the determination of work areas that are possible health hazards.
- Control of hazardous noise exposure by engineering measures if possible.
- Consideration of the elimination or reduction of noise exposures in the planning and development of future operations and in the purchase of new equipment or machinery.

- Measurement of hearing ability of all personnel exposed to excessive noise levels (also called audiometric examinations prior to on the job activity and at regular intervals thereafter).
- Use of personal hearing protection devices such as earplugs or muffs wherever the noise cannot be adequately controlled by administrative or engineering measures.

Some companies have found it very helpful to use employee education as an approach to a hearing conservation program. Figure 8 shows a sample card one company issued to all of its employees concerning the purpose, benefits, and instructions for wearing hearing protectors.

LET'S REVIEW THE FACTS

1. It is necessary for employees in certain noisy areas to wear ear protectors
2. Prolonged exposure to excessive noise can harm the delicate hearing mechanism
3. Ear protectors such as ear plugs or ear muffs will reduce the noise before it reaches the ear drum
4. Your job assignment will determine whether you should wear ear plugs (inserts) or muffs (covers)
5. Speech and warning signals can be fully heard with ear portectors in noisy shop areas

WEAR YOUR EAR PROTECTORS

1. The nurse will fit them and instruct you how to wear them
2. Wear them for short periods to start and gradually increase the wearing time. After a few days you will be able to wear them all day with minimum discomfort

Suggested Wearing Time Schedule

	a.m.		p.m.
1st day =	30 minutes	–	1 hour
2nd day =	1 hour	–	1 hour
3rd day =	2 hours	–	2 hours
4th day =	3 hours	–	3 hours
5th day =	all day	–	all day thereafter

3. If after five days the ear protectors feel uncomfortable, come in and see the nurse in the company hospital
4. Ear protectors should be replaced when they become worn, stiff or lose their shape
5. If ear protectors are misplaced, a new pair should be obtained without delay
6. Never put soiled ear plugs into your ears. Wash the ear plugs at least once a day with soap and water
7. With proper care, ear plugs should last for several months and ear muffs should last for several years

OTHER POINTS TO REMEMBER

1. The best ear protector is the one that is properly fitted and worn
2. Good protection depends on a snug fit. A small leak can destroy the effectiveness of the protection
3. Ear plugs tend to work loose as a result of talking or chewing, and they must be reseated from time to time during the working day
4. If ear plugs are kept clean, skin irritations and other reactions should not occur

YOUR HEARING IS PRICELESS

PROTECT IT

Figure 8. A sample of a card that one company issues to all of its employees who are required to wear some form of protective hearing device.

Industrial noise problems are extremely complex. Thus there is no one "standard" program that can be used in every situation. For those businesses and individuals needing assistance in establishing hearing conservation programs, services are available in a number of professional areas through private consultation, insurance and governmental groups.

ACTIVITY 9:

1. Circle the correct answer:
   A successful hearing conservation program requires cooperation from:
   a. the employees.
   b. management.
   c. consulting experts.
   d. All of the above.
2. List five general procedures for carrying out an industrial hearing conservation program.
   a. _____
   _____
   b. _____
   _____
   c. _____
   _____
   d. _____
   _____
   e. _____
   _____

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ANSWERS TO ACTIVITIES

ACTIVITY 1

1. Noise is any unwanted sound.
2. a. A source (that gives off sound energy).
   b. A path (along which sound energy travels).
   c. A receiver (of the sound).

ACTIVITY 2

1. a. Amplitude - how loud or intense the sound is.
   b. Frequency - the pitch (highness or lowness) of the sound.
   c. Duration - how long the sound lasts.
2. a. dB - decibel, measures the fullness of sound.
   b. Hz - Hertz, measures the frequency or pitch.

ACTIVITY 3

1. Physiological effects - loss of hearing, stress, ulcers, heart disease (any one).
2. Psychological effects - annoyance, lack of sleep (either one).
3. Interference with communication and job performance - loss of ability to communicate, hindering of job performance and work quality, accidents (any one).

ACTIVITY 4

   c. Avoid the problem to begin with.

ACTIVITY 5

1. Minimize the source - modify or replace equipment; modify technological approaches; properly maintain equipment; muffle exhausts; change operational procedures (any one).
2. Interrupt the path - use sound-absorbing materials; shield or enclose the source; increase the distance between the sound and the receiver; place a shield between the source and the receiver (any one).
3. Protect the receiver - enclose or shield the receiver; rotation of jobs and personnel; ear plugs and ear muffs (any one).

ACTIVITY 6

1. Ear plugs - provide an acoustical seal at the entrance of the ear canal; must be properly fitted (any one).
2. Ear muffs - worn over the external ear; provide an acoustical seal against the head (either one).

ACTIVITY 7

1. Replace vibrating machines - too expensive.
2. Reduce the machine speed - slow down production.
3. Regular maintenance - saves wear and tear on machine; is least costly.
4. Vibration isolation - relatively inexpensive.

ACTIVITY 8

1. 1 hour.
2. a. True.
   b. False.
   c. False.

ACTIVITY 9

1. d.
2. See bulleted list on page 26.